Recovery of dynamic lung function in elite judoists after short-term high intensity exercise

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Manuscript Preparation
E Funds Collection

Dragan Radovanovic[ABCDE], Milovan Bratic[CDE], Mirsad Nurkic[BD], Nemanja Stankovic[BD]

Faculty of Sport and Physical Education, University of Nis, Nis, Serbia

Source of support: Faculty of Sport and Physical Education and authors' own financial resources

Received: 9 February 2011; **Accepted:** 12 February 2011; **Published online:** 21 February 2011

Abstract

Background and Study Aim: Changes to lung volume and capacity occur after intense power output. The aim of this investigation was changes in the parameters of dynamic lung function after short-term high intensity exercise and the correlation between the above mentioned parameters before and after exercise.

Material/Methods: Changes to the parameters of dynamic lung function (forced vital capacity – FVC, forced expiratory volume during the first second – $FEV_{1.0}$, and peak expiratory flow – PEF) were studied on a sample consisting of 11 elite judoists (age 21±2.41 years; height 176.63±7.43 cm; weight 75.55±8.91 kg; body fat 8.25±4.38%; VO_{2max} 54.99±4.11 $mL\cdot kg^{-1}\cdot min^{-1}$).

Results: Before and after "all out" Wingate test (peak power 11.95±0.79 $W\cdot kg^{-1}$; mean power 8.18±0.48 $W\cdot kg^{-1}$). There are significant difference ($p<0.001$) among the average values of FVC (1.67±0.63 L or 25.39±9.1%), $FEV_{1.0}$ (1.08±0.5 L or 21.1±9.13%) and PEF (1.85±0.36 $L\cdot s^{-1}$ or 17.9±3.99%) which were determined over different periods of time in relation to "all out" test carried out on the subjects. The positive correlation among the FVC, $FEV_{1.0}$ and PEF determined before the „all-out" test, with the same lung function parameters determined after the test, can indicate that the extent of the manifested power, for elite judoists, has no negative influence on the recovery of dynamic lung function.

Conclusions: A lesser reduction in dynamic lung function after short-term high intensity exercise enables a quicker recovery between consecutive attacks, which creates the necessary functional conditions for scoring better results at competitions.

Key words: judo • power • lung function tests • training effect • recovery

Author's address: Dragan Radovanovic, Department of Exercise Physiology, Faculty of Sport and Physical Education, University of Nis, Carnojevica 10A, 18000 Nis, Serbia; e-mail: dornaniste@yahoo.com

Background

Judo is a dynamic and physically demanding sport which is characterized by alternations between maximum intensity, lasting on average 15–30 s, and rest periods, lasting around 10 s [1]. This is the reason why judoists primarily engage the anaerobic part of their bioenergetics capacity [2]. A large number of different variables (physiological, technical, tactical and psychological) determine the final (competitor's) result in judo. Over the last three decades, several studies have been carried out with the aim of analyzing the requirements that a judoist has to meet in order to score top results [3–7]. For the past decade, studies have focused on the relations between the cited variables in situations which are characteristic for this kind of sport [8,9]. Franchini et al [10] have shown that the morphological and functional characteristics of judoists correlate with the technical elements carried out during a match. It is therefore possible that any improvement to one of the cited variables can have a positive effect on the rest of them. Our research so far has indicated that changes to the plan and program of a six-week training program right before a competition can result in serious changes even for the competitors who have been part of the training process for years [11]. Physiological profile of judo

Judo – Literally meaning "the way of softness and flexibility", a martial art (budo) created by Jigoro Kano [30]. Judo is a complex sport where many variables (tactical, technical, physiological, psychological) determine the final result [10].

Power – The rate of performing work; the product of force and velocity. The rate of transformation of metabolic potential energy to work or heat (SI unit: watt) [14].

competitors is not easy to determine because differences in body mass, stature and body composition. Gariod et al. [12] have, by analyzing high energy phosphates by means of a spectroscopic magnetic resonance using a spectroscopic method of nuclear meagnetic resonance with a 31P, determined two dominant profiles of judoists: the aerobic and anaerobic one. Judoists who usually win during the final minutes of the match are said to be of the aerobic profile, while the judoists who usually win at the beginning of the match are usually said to be of the anaerobic profile. The decrease in the amount of creatine phosphate during a maximal voluntary contraction was smaller in the case of judoists belonging to the aerobic profile, but the re-synthesis of the creatine phosphates was quicker in comparison to the judoists who belonged to the aerobic profile [13]. These results indicate that physiological and biochemical processes directly influence the manner in which the match takes place, as well as the application of technical and tactical elements during a match.

During physical activity which is of a lesser intensity, what primarily increases is the value of respiratory volume in relation to the frequency of respiration. In the case of physical activity from middle to maximal intensity, respiratory volume increases up to 50% of the maximal capacity [14]. Respiratory frequency during activities of maximal intensity is: in the case of children aged 5, around 70 breaths$\cdot$min^{-1}, children aged 12 around 55 breaths$\cdot$min^{-1}, and adults aged 25, 40–45 breaths$\cdot$min^{-1} [15]. In the case of fit athletes, who have great values of aerobic capacity, respiratory frequency reaches around 60 breaths$\cdot$min^{-1} [16].

The ability to retain a high level of air flow depends on the speed at which a certain volume can be changed during a respiratory cycle, as well as on it size. Dynamic functions can be studied during a short period of hyperventilation or during individual maximal respiratory strain. Dynamic lung function is usually evaluated [17] by measuring the forced vital capacity (FVC), forced expiratory volume during the first second ($FEV_{1.0}$) and peak expiratory flow (PEF).

Changes to lung volume and capacity occur after intense power output. After the „all-out“ activities of certain athletes, especially rowers, respiratory problems such as coughing accompanied by expectoration and dyspnea can occur [18]. The cough can last for several days. A decrease in FVC immediately after an activity [19], reduction in PEF and an increase in residual volume are all part of the findings described in previous research [18,20,21].

The aim of this investigation was changes in the parameters of dynamic lung function after short term intensity exercise and the correlation between the above mentioned parameters before and after short-term high intensity exercise.

Material and Methods

A total of 11 male subjects (age 21±2.4 years, height 175.6±7.4 cm, weight 75.5±8.9 kg, body fat 8.2±4.4%) participated in the investigation. All of the subjects were elite judoists (winners and medal recipients at the national championships of Serbia, winners and medal recipients at championships of the Balkan region, participants of the University games and European championships), with years of experience at competitions. All of the subjects were presented with the relevant information in written form regarding the aims, course, participation and possible unwanted side effects of the investigation. All of the subjects voluntarily gave their written consent to participate in the investigation, and underwent a general physical examination. None of the subjects showed any evidence in their anamnesis or clinical report about exercise-induced bronchoconstriction.

The investigation protocol consisted of anthropometric measurements (weight, height, body fat), functional tests (estimation of VO_{2max} and Wingate test, because of its characteristics such as short duration and standardized protocol, a 30-s „all-out“ Wingate test was used as an high-intensity exercise), and monitoring of lung function using the method of computerized spirometry. Body height was measured by means of an anthropometry (GPM, Switzerland) and in accordance with standardized procedure [16]. The results of the measuring's were accurate within 0.1 cm. Body weight was measured by means of electronic scales (Tefal, France) with an accuracy within 0.1 kg. To analyze bioelectrical impendence [22,23] the BF device (Omron, Japan) was used. Data regarding percentage of fatty tissue were read off the display with an accuracy of 0.1%. Maximum oxygen uptake (VO_{2max}) was estimated by standardized 6 minute submaximum test on the leg cycle ergometer (Kettler, Germany) along with telemetric monitoring of heart function (Polar, Finland). The setting up of the equipment and the subjects' warm-up carried out according to the standard. Data calculation was carried out with the help of specially designed software on the basis of a series of polynomial equations based on the Astrand-Ryhming nomogram [17]. The testing was carried out at least 24 hours prior to the measuring of dynamic lung function and the execution of the "all-out" Wingate test.

The anaerobic capacity parameters were determined by the "all-out" 30-s anaerobic Wingate test [24,25]. For this purpose, a cycle ergometer equipped with an

Table 1. The anthropometric and functional characteristics of the judoists (n=11).

Variables	Means ±SD	Min-max
Age (years)	21.00±2.41	18–27
Body height (cm)	176.63±7.43	163.10–192.60
Body weight (kg)	75.55±8.91	63.30–86.40
Body fat mass (%)	8.25±4.38	3.80–15.20
VO_{2max} (ml·kg^{-1}·min^{-1})	54.99±4.11	49.95–62.54
Peak power (W·kg^{-1})	11.95±0.79	10.89–13.42
Mean power (W·kg^{-1})	8.18±0.48	7.59–8.98
FVC (L)	6.52±0.74	5.77–8.23
$FEV_{1.0}$ (L)	5.10±0.52	4.25–5.95
PEF (L·s^{-1})	10.40±0.96	9.15–11.95

FVC – Forced Vital Capacity; $FEV_{1.0}$ – Forced Expiratory Volume during the first second; PEF – Peak Expiratory Flow.

Table 2. The lung capacity parameters after the "all-out" test.

II	Means ±SD	Min-max
FVC (L)	4.85±0.69	4.00–6.14
$FEV_{1.0}$ (L)	4.02±0.61	3.18–4.99
PEF (L·s^{-1})	8.55±1.01	7.06–10.1
III		
FVC (L)	5.54±0.69	4.89–6.96
$FEV_{1.0}$ (L)	4.48±0.5	3.76–5.13
PEF (L·s^{-1})	9.44±0.87	7.93–10.84
IV		
FVC (L)	6.09±0.71	5.36–7.86
$FEV_{1.0}$ (L)	4.84±0.51	3.98–5.55
PEF (L·s^{-1})	10.02±0.9	8.65–11.46

FVC – Forced Vital Capacity; $FEV_{1.0}$ – Forced Expiratory Volume during the first second; PEF – Peak Expiratory Flow; II – The second measurement was done after the test, immediately after the heart rate frequency decreased bellow 120 beats·min^{-1}'; III – The third measurement was done 60 s after the completion of the second; IV – The fourth 120 s after completing the second measurement.

electronic measuring device with a display was used (Siemens, Germany). The setting up of the equipment and the subjects' warm-up carried out according to the standard. Data registration was carried out with the help of specially designed software on the basis of the standards devised by the author of the test [24] and the published technical description of a system for registering data by means of a computer [26].

A computerized spirometer was used to monitor changes to respiratory functions by means of the FVC, $FEV_{1.0}$ and PEF parameters (Cosmed, Italy). Subjects were required to perform FVC maneuvers on computerized spirometer according to standards [27] in a total of four measurings. The first measurement (I) was done before the warm up procedure for the 30-s "all-out" Wingate test. The second measuring (II) was carried out right after the completion of the test, with the exception that the subjects had to leave the cycle ergometer when their heart rates reached levels below 120 beats·min^{-1}. The third measuring (III) was carried out 60 seconds after the completion of the second measuring procedure. The fourth measuring (IV) was carried out 120 seconds after the completion of the second measuring procedure.

The testing was carried out in a room where the temperature was 21–23°C, where the humidity was 55–60%, so that the microclimatic conditions followed the standards for functional lab testing.

Data analysis

In order to test the normality of the distribution of the studied features, the Shapiro-Wilk's Test was used. In cases where the distribution deviated in a statistically significant manner from the normal values, some non-parameter tests were used. Levene's Test was used as the test to study the homogeneity of variance between the groups.

The one-way analysis of variance (One-Way ANOVA) and the Tukey HSD Post Hoc Test were used to check the differences in the average values between the repeated determinations of the lung functions (FVC, $FEV_{1.0}$ and PEF) at different intervals, in relation to the "all out" test of the subjects. The correlation of the lung function parameters was checked by means of the Pearson coefficient of linear correlation.

The correlation between the subjects' fat tissue, and lung function parameters (FVC, $FEV_{1.0}$ i PEF), and anaerobic endurance parameters was investigated by Spearman's rank correlation coefficients (Spearman's rho – ρ).

In order to process the results of the study, the Statistical Package for the Social Sciences (SPSS) for Windows (Release 10.0, USA) was used.

Results

The obtained results are shown in Tables 1–5.

The anthropometric and functional characteristics of the judoists are shown in Table 1.

Lung function tests – are widely employed to assess respiratory status. In addition to their use in clinical case management, they are routinely used in health examination in respiratory, occupational and sports medicine, and for public health screening [16].

Training effect – Physiological adaptation to repeated bouts of exercise [14].

Recovery – is physiological processes taking place in the period following an acute bout of exercise when the body is restored to its pre-exercise condition. Recovery processes include replenishment of muscle glycogen and phosphagen stores, removal of lactic acid and other metabolites, reoxygenation of myoglobin and protein replacement [31].

Table 3A,B. The values of the lung capacity parameters of the subjects (means ±SD) before and after the "all out" test.

A Variables	Before the »all out« test	After the »all out« test		
		II	III	IV
FVC (L)*	6.52±0.74	4.85±0.69	5.54±0.69	6.09±0.71
$FEV_{1.0}$ (L)*	5.10±0.52	4.02±0.61	4.48±0.5	4.84±0.51
PEF ($L\cdot s^{-1}$)*	10.40±0.96	8.55±1.01	9.44±0.87	10.02±0.9

*p<0.001

B Variables	F	p
FVC (L)	11.355	p<0.0001
$FEV_{1.0}$ (L)	8.416	p<0.001
PEF ($L\cdot s^{-1}$)	8.165	p<0.001

FVC – Forced Vital Capacity; $FEV_{1.0}$ – Forced Expiratory Volume during the first second; PEF – Peak Expiratory Flow; II – The second measurement was done after the test, immediately after the heart rate frequency decreased bellow 120 beats·min^{-1}; III – The third measurement was done 60 s after the completion of the second; IV – The fourth 120 s after completing the second measurement.

Table 4. The Pearson coefficient of the linear correlation of the lung capacity parameters before the test with the same parameters after the "all out" test.

Variables	After the »all out« test		
	II	III	IV
FVC (L)	0.614*	0.831**	0.936***
$FEV_{1.0}$ (L)	0.62*	0.663*	0.908***
PEF ($L\cdot s^{-1}$)	0.935***	0.804**	0.847***

* p<0.05; ** p<0.001; *** p<0.0001.
FVC – Forced Vital Capacity; $FEV_{1.0}$ – Forced Expiratory Volume during the first second; PEF – Peak Expiratory Flow; II – The second measurement was done after the test, immediately after the heart rate frequency decreased bellow 120 beats·min^{-1}; III – The third measurement was done 60 s after the completion of the second; IV – The fourth 120 s after completing the second measurement.

The average values of the lung function parameters decreased significantly after the "all-out" test, and then their values grew gradually (Table 2).

There is a statistically significant difference (p<0.001) in the average values of FVC, $FEV_{1.0}$ and PEF which are determined over different periods of time in relation to the test of the subjects (Table 3A,B).

The greatest decrease in the value of the lung function was noted right after the test. The forced vital capacity (FVC), on average, decreased by 1.67 L±0.63 or by 25.39±9.1%. This decrease is of great statistical significance (t=8.785; p<0.001).

The forced expiratory volume during the first second ($FEV_{1.0}$) immediately after the test had average values of 1.08 L±0.5 or 21.1%±9.13. The decrease is highly statistically significant (t=7.173; p<0.001).

The value of the peak expiratory flow (PEF) immediately after the "all out" test is smaller in relation to the value before the test, on average, by 1.85 $L\cdot s^{-1}$±0.36 or 17.96±3.99%. The difference in the average values of PEF immediately prior to and after the test is highly statistically significant (t=17.044; p<0.001).

The correlation between the FVC, $FEV_{1.0}$ and PEF, which were determined before the test, with the same parameters of lung function determined after the test, is positive and statistically significant (Table 4). The correlation between the subjects' fat tissue and anaerobic endurance parameters (Table 5) is negative (the higher fat tissue percentage, the lower PP and MP) but it is not statistically significant (Spearman's p>0.05).

Discussion

The results obtained by investigating the judoists' functional characteristics show that the values of VO_{2max} are at the average athletes' level, but they are close to the VO_{2max} values measured in elite judoists [4–6,9–11]. With regards to the previously described characteristics of judo as a sport, we consider this to be an expected result and an indicator of a good aerobic preparation. The parameters of anaerobic capacity determined by the Wintgate test (peak and mean power) are expectedly high having in mind the sample of elite competitors, and they are similar to the results of our

Table 5. The Spearman's coefficient (ρ) of correlation of the subject's body fat with lung capacity parameters before and after the „all-out" test.

Variables	ρ before the »all out« test	After the »all out« test		
		II	III	IV
FVC (L)	0.26	0.292	0.296	0.378
$FEV_{1.0}$ (L)	0.355	0.237	0.41	0.428
PEF ($L \cdot s^{-1}$)	0.154	0.247	0.361	0.369

previous investigations as well as the investigations of other authors.

The obtained results have indicated a significant decrease in the values of the studied parameters of lung function immediately after short-term high intensity bouts of exercise during the Wingate test. The greatest decrease after the test was noted for forced vital capacity (for about 25%) which can be interpreted by a greater influence of fatigue of the breathing muscles, considering the fact that expiration during forced spirometry lasts on average for 3 seconds, in comparison to the study of the $FEV_{1.0}$. The decrease to the $FEV_{1.0}$ after the test is statistically significant on average by around 21%. The values of the PEF after the test have decreased by around 18%, which is also statistically significant. During the third and fourth measuring a gradual increase in the values of the studied parameters was noted. The inspiratory muscles (which undertake the majority of the mechanical work of breathing) have been shown in previous studies to exhibit fatigue after both short, high intensity bouts of exercise [28,29].

The mean values of the parameters of lung function decreased suddenly, immediately after a short-term power output, and then their values grew gradually during the period of recovery. There is a statistically significant difference in the values of FVC, $FEV_{1.0}$ and PEF which were determined at various intervals in relation to maximum power output in relation to the "all-out" anaerobic test of the subjects.

The results of previous research [18,29] also place much emphasis on the study of changes to lung function as one of the basic points of the functional fitness of athletes, but as part of physical activity with primarily aerobic demands. The aforementioned research was aimed at the changes in lung function during a period of 5–30 min after power output [19,20]. Considering the fact that a judo match lasts for a total of 5 min, as part of our research, changes were monitored over a very short period of time, after maximum physical activity, which suits the characteristics of a judo match. However, this kind of planning and execution made the direct comparison of data with the research that is familiar to us impossible.

A positive correlation between the FVC, $FEV_{1.0}$ and PEF, which were determined before the short-term power output, with the same parameters of lung function, determined after the test, indicates that in the case of elite judoists, the extent of the manifested power does not have a negative influence on the recovery of dynamic lung function. This can be considered the greatest degree of functional adaptation in relation to the specific demands of judo as a competitive sport. A smaller reduction of lung function after maximum power output enables a quicker recovery between consecutive attacks, which creates the necessary functional conditions for better results at competition. The possible factors which contribute to the described temporary changes to lung volume after power output are: changes to the volume of circulating blood, changes to the mechanics of breathing, fatigue of the breathing muscles and the development of subclinical extravascular lung retention of fluid [16]. Due to the aforementioned, we consider that monitoring the parameters of lung function and the changes to them during physical activity of high (submaximal and maximal) intensity can give a precise insight into the functional state of athletes.

The correlation between the subjects' fat tissue and lung function parameters (FVC, $FEV_{1.0}$, PEF) regardless of the measurement time is positive (the higher fat tissue percentage, the higher values of parameters), but not statistically significant (Spearman's $p>0.05$). The correlation between the subjects' fat tissue and the changes in lung function parameters (FVC, $FEV_{1.0}$, PEF) is positive at one time and negative at another, for the reason that the variability of changes is extremely high, as well as the variability of the subjects' fat tissue percentage – it is not statistically significant (Spearman's $p>0.05$).

Conclusions

The positive correlation between FVC, $FEV_{1.0}$ and PEF, which were determined before the "all-out" test, with the same parameters of lung function determined after the test, indicates that in the case of elite judoists, the extent of the manifested power does not have a negative influence on the recovery of lung function. This can be considered the greatest degree of functional adaptation in relation to the specific demands of judo as a competitive sport. A smaller reduction of lung function after maximum power output enables a quicker recovery between consecutive attacks, which creates the necessary functional conditions for better results at competitions.

The obtained data from our research indicate that changes to dynamic lung function can be used as an indicator of functional fitness and even in the case of physical activity which is dominantly anaerobic. Although our research is limited in term of number of participants, dealing with elite athletes may help identify some of major determinants needed to attain the best performance capacity in judo competitors. Similar studies involving subjects who participate in similar sports (boxing, wrestling, karate, etc.) due to the kind of energy demands on physical activity, the duration of the match and the type of tournament, are necessary for the confirmation of our results. This would lead to the determination of this kind of test as the standard in the functional diagnostics of elite athletes.

References:

1. Sterkowicz S, Franchini E: Tehniques used by judoists during the World and Olympic tournaments 1995–1999. Hum Mov, 2000; 2: 24–33
2. Pulkkinen WJ: The sport science of elite judo athletes: a review and application for training. Guelph (Ontario): Pulkinetics, 2001
3. Classens AL, Beunen GP, Wellens R, Geldof G: Somatotype and body structure of world top judoists. J Sport Med, 1987; 27: 105–13
4. Thomas SG, Cox MH, Legal Y, Verde TJ: Physiological profiles of the Canadian national judo team. Can J Sport Sci, 1989; 3: 142–47
5. Callister R, Callister RJ, Staron RS: Physiological characteristics of elite judo athletes. Int J Sport Med, 1991; 12: 196–203
6. Ebine K, Yoneda I, Hase H: Physiological characteristics of exercise and findings of laboratory tests in Japanese elite judo athletes. Med Sport, 1991; 65: 73–79
7. Bratic M, Djuraskovic R: Somatometrical characteristics and functional abilities of high quality young judo fighters. Iugoslav Physiol Pharmacol Acta, 2000; 36(2): 57–66
8. Kim KJ, Kim EH, Han MW: A comparation of physiological and performance responses for analysis of the degree of judo training intensity. Kor J Sport Sci, 1996; 8: 52–64
9. Borkowski L, Faff J, Straczewska-Czapowska J: Evaluation of the aerobic and anaerobic fitness in judoists from the Polish national team. Biol Sport, 2001; 18: 107–17
10. Franchini E, Takito MY, Bertuzzi RCM: Morphological, physiological and technical variables in high-level college judoists. Archives of Budo, 2005; 1: 1–7
11. Radovanovic D, Bratic M, Nurkic M, Vukajlovic V: Effects of specially designed judo training on anaerobic and aerobic capacity in young judo competitors. In Christodoulus C, editor. Proceedings of the 4th European Sports Medicine Congress; 2005 Oct 11–15; Lemesos, Cyprus. Bologna: Medimond SrL; p. 111–15
12. Gariod L, Favre-Juvin A, Novel V et al: Evuluation du profit energetique des judokas par spectroscopie EMN du P31. Sci Sport, 1995; 10: 210–17 [in French]
13. Gariod L, Binzoni T, Ferretti G et al: Standardization of 31phosphorus-nuclear magnetic resonance spectroscopy determinations of high energy phosphates in humans. Eur J Appl Physiol, 1994; 68(2): 107–10
14. Wilmore JH, Costill DL Kenney LW: Physiology of sport and exercise. 4th edition. Champaign (IL): Human Kinetics, 2008
15. West JB: Respiratory physiology. 6th ed. London: Lippincott Williams & Wilkins, 1999
16. Eston R, Reilly T: Kinanthropometry and exercise physiology laboratory manual: tests, procedures and data. Volume 2: Exercise physiology. 2nd ed. London: Routledge, 2001
17. American College of Sports Medicine: Guidelines for exercise testing and prescription. 7th ed. Baltimore: Lippincott Williams & Wilkins, 2006
18. Rasmussen RS, Elkjaer P, Juhl B: Impaired pulmonary and cardiac function after maximal exercise. J Sport Sci, 1988; 6: 219–28
19. Miles DS, Cox MH, Bomze JP, Gotshall RW: Acute recovery profile of lung volumes and function after running 5 miles. J Sport Med Phys Fit, 1991; 31(2): 243–48
20. Buono MJ, Constable SH, Morton AR et al: The effect of an acute bout of exercise on selected pulmonary function measurements. Med Sci Sport Exer, 1981; 13(5): 290–93
21. Quindry JC, Brown DD, McCaw ST, Thomas DQ: Effect of exercise-induced changes in residual lung volume on the determination of body composition. J Strength Cond Res, 2002; 16(4): 591–98
22. United States National Institute of Health Tehnology (US): Bioelectrical impedance analysis in body composition measurement. Assement conference statement. Am J Clin Nutr, 1996; 64: 524–36
23. Chumlea WC, Guo SS, Kuczmarski RJ et al: Body composition estimates from NHANES III bioelectrical impendance data. Int J Obes Rel Met Dis, 2002; 26: 1596–609
24. Inbar O, Bar-Or O, Skinner JS: The Wingate anaerobic test. Champaign (IL): Human Kinetiks, 1996
25. Beneke R, Pollmann C, Bleifi K et al: How anaerobic is the Wingate anaerobic test for humans. Eur J Appl Physiol, 2002; 87: 388–92
26. Inesta JM, Izquierdo E, Angeles-Sarti M: Software tools for using a personal computer as a timer device to assess human kinetic performance: a case study. Comput Meth Prog Biomed, 1995; 47: 257–65
27. American Thoracic Society (US): ATS statement – standardization of spirometry. 1994 update. Am Rew Res Dis, 1995; 152(5): 1107–36
28. Johnson BD, Babcock MA, Suman OE, Dempsey JA: Exercise-induced diaphragmatic fatique in healthy humans. J Physiol, 1993; 460: 385–405
29. Lomax ME, McConnell AK: Inspiratory muscle fatigue in swimmers after a single 200 m swim. J Sport Sci, 2003; 21(8): 659–64
30. Kawamura T, Daigo T: Kodokan New Japanese-English Dictionary of Judo. Tokyo: The Foundation of Kodokan Judo Institute, 2000
31. Kent T: The Oxford Dictionary of Sports Science and Medicine. 3rd edition. Oxford-New York-Tokyo: Oxford University Press, 2006